UNITED STATES DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU SOUTHERN REGION
Fort Worth, Texas

TECHNICAL MEMORANDUM NO. 7

SHORT PERIOD FORECASTING

by

Jeter A. Pruett
Assistant Regional Meteorologist
Fort Worth, Texas

Scientific Services Division

November 1965

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The Setting of Short Range Forecasting

Synoptic and macroscale weather chart plotting, analysis and prediction and, to a great extent, the translation into forecasted weather patterns gradually have been transferred to the National Meteorological Center in the interest of economy, accuracy, and compatability between sections of the country. Weather Bureau policies relating to field forecast activities contain these basic points:

> NMC products produce good translations into weather patterns for periods beyond twenty-four hours. Field efforts should not duplicate those of NMC.
>
> Forecast Center scope of operations deals primarily with the period six to twenty-four hours in the future.
>
> Local office forecast functions pertain primarily to the first six hours of the local, community, or zone forecast and blending these expectations with the latter part of the twelve hour interval spelled out by forecast center guidance.

During the decades of expanding facsimile coverage and centralized synoptic scale forecasting, field skills in air mass forecasting techniques, chart plotting, analysis, and progging of weather systems have deteriorated from lack of use. Most concentrated research has by-passed short range forecasting with major emphasis being placed upon large scale models designed for computer application and upon studies allied to space exploration. Now, in the shake-down of forecast programs following the evolution of centralized forecasting, revitalization of tools and skills of "manual" forecasting is necessary to bridge the short period gap left by centralized forecasting.

Basis for Emphasizing Short Period Forecasts

The need for shoring-up our short-term forecast capability is easily recognized. The expanding concept of providing community forecasts increases the attention needed to the early part of the public forecast. Increased aircraft performance is steadily shortening the time span for flights, and for aviation interests the primary focus is on periods of less than six hours. Effective resource sharing in pilot briefing requires high quality terminal forecasts, In-flight Advisories, and back-up capability to the briefer on the line. The potential usefulness of "short-fuse" warnings and public forecast amendments of an immediate nature is growing as we make steady progress in adopting communications technology to user weather needs. As examples, one can point to the extensive radio facilities available for aviation weather dissemination, to automatic telephone answering facilities, to public and ag-met teletype loops, to emergency weather broadcasts over lash-ups of commercial radio stations, and to Civil Defense advances in developing communications nets. We can look for further impetus to be given our capability for producing "real time" high quality warnings as the ESSA concept of a Natural Disaster Warning System becomes operational.

Mesoscale Concepts

Dickey, in Southern Region Technical Memorandum No. 1, pointed out that the small scale analysis program likely would hinge about the mesoscale extending an order of magnitude upward to the small synoptic and downward to the local scale. Schroeder (18) has coined the word topometeorology to describe the interplay between site and weather - the funnel wind, the coastal effect, the local orography, the "freak" local storm. This is an integral part of the local forecast problem, and the ability best to recognize topometeorological features is at the lowest echelon of the forecast hierarchy. The mesoscale system is a short-lived one and must be handled, forecast-wise, at the local level under our organization and policies. It follows that techniques to relate local phenomena to the parent synoptic or mesoscale configuration - and then to forecast them - should be developed at the local office.

The local office has a critical and continual weather watch responsibility as outlined in Regional Headquarters Memorandum of April 14, 1965, Technique Improvement for Small Scale Analysis and Short Period Forecasts. An up-to-date forecast is always available to the public from our local offices under these concepts. The analysis and forecast programs of local stations to meet these responsibilities must be continual, dealing with at least hourly data and with a considerable degree of independence time-wise from regularly scheduled 6- or 12-hourly guidance materials. The variations in cloudiness, wind, temperature, and precipitation which frame the short term forecast problem are related to the systems of the approximate order of mesoscale.

There is a considerable amount of available literature about mesoscale phenomena and their analysis. Forecasters and local program planners should review Weather Bureau Research Paper No. 39 (11) and a related article in February 1959 BAMS (19). These papers explain concepts of mesoscale pressure systems, their relation to severe weather, and clues to their development and movement. Warning justifying winds associated with extreme convection, shear, and downward transport of momentum from low level jets have dynamic and kinematic roots in the mesoscale properties discussed.

Radar Utility

The density and frequency of observations and short time factors typical of sample mesoanalyses may be discouraging when consideration is given to operational procedures based upon manual means of collecting and treating data. But precipitation systems in the mesoscale result in very graphic and continuous radar scope displays of such features as the squall line and spiral bands. Important fluctuations of the type and intensity of precipitation and timing the onset and ending are directly related to radar intelligence. Persistence and steering principles for radar patterns are well documented in literature and are being used routinely to varying degrees at field stations.

Technical Note No. 17, The Use of Radar in Short Period Forecasting (13), summarizes objective and subjective techniques applicable to radar data.

Under the umbrella concept of surveillance and continual weather watch, it is mandatory that quantitative radar intelligence and prognoses from it be fed into short range forecast programs routinely as well as during potential severe storm periods. Radar is the most versatile tool we now have for dealing with mesoscale configurations, and stations should make maximal use of radar technology and resources in meeting short range forecast responsibilities.

Meso- versus Macroscale

In treating small space and time scale weather phenomena, forecasters naturally and logically desire to draw upon synoptic and macroscale techniques familiar through training and experience. All scales of weather analysis have certain common physical and dynamic principles, but there are certain antitheses. Macroscale analysis deals with amplitudes up to thousands of miles and periods of days. Incipient synoptic developments and transient mesoscale fields of motion imposed on the long waves are the crux of the forecast for the next few hours. These are measured in hundreds of miles and hours. Macroscale analysis takes advantage of long term natural tendencies for the atmosphere to seek and maintain a quasi-state of balance. Resulting are approximations of geostrophic flow, hydrostatic equilibrium, adiabatic processes, and the steady state. A main thesis in macroscale and synoptic prediction is that features are translated with the wind flow. Small space and time scale configurations are filtered out as noise.

As the scales approach the topometeorological, greater preciseness is demanded because local weather changes are influenced more by physical processes than by changes due to advection. The "filtered noise" of the macroscale becomes the essence of the small scale. Second order terms such as accelerations become important, as do fluxes of radiation and the sensible heat sources and sinks that drive the processes of non-advective change. Thus day-by-day and diurnal insolation variations require primary attention. Transformations of energy by evaporation-condensation processes are relatively unimportant over a few hours period, but moisture accounting becomes necessary because most weather changes are basically tied to moisture state changes.

Some reorientation of thinking processes is necessary as the forecaster transits from tomorrow's weather to that of the next few hours. A pragmatic analysis of the potential of existing data for short range forecasting is contained in the research report of Aerometric Research, Inc.: Mesoscale Analysis of Existing Meteorological Network Data (10). It should be reviewed for examples of methods of treating data to improve short period forecasting. These are some main points brought out that should be considered as stations work to upgrade their small scale analysis programs:

> Surface analysis techniques are considerably enhanced by complementary sounding and upper air considerations.

> Advection accounts poorly for small scale weather changes and the local time deriviative (physical processes) is a dominant factor.

Features obtained directly from radar scopes are much more useful in short period forecasting than RAREPS or Radar Summary information.

Denser surface and upper air nets and more frequent soundings are required to describe the state of the atmosphere upon which to base short and detailed forecasts.

Physical Processes and Extrapolation

Synoptic-extrapolation techniques account for most of the skill in present day-by-day forecasting. Especially in the short run, extrapolation techniques account for accelerations, deformations, and some of the dominance of physical processes over advection. Weather changes due to physical processes occur in a sample of air as it is carried along in the basic flow. While this effect is physically and mathematically independent of translation, it is reflected to a degree in the positions of resulting weather patterns and isochrones. As the air sample is modified by moving through source gradients of moisture or heat, extrapolation by small increments partially traces resulting changes.

A limitation to extrapolation methods is imposed by certain critical levels at which processes such as condensation and auto-convection set in. This is a basic forecast problem, for instance, in timing the conversion of a moving "dry" trough or convergence zone into a weather producer. Success has been shown in compositing extrapolations of individual parameters to forecast such mesoscale features as outbreaks of severe thunderstorms (17).

The Composite Synoptic Picture

In tackling the job of bridging the gap from facsimile chart and FP guidance to the small time scale, the forecaster first must study the synoptic scale fax charts for apparent data-analysis mis-fits or anomalies for clues to the need for magnification. In this process there is a required amount of synthesis. Flow patterns in relation to thermal, moisture, and vorticity patterns are shown on several different charts. Current weather is shown on surface maps, weather depiction and radar summary charts. Each is full of information, but there are salient features on each of special interest to the local forecaster because of their influence on the weather to be expected in the next few hours. These he can identify by marking them on the individual fax charts and correlating one with the other on a common plastic overlay. Fronts, ridge and trough lines, and perhaps significant dew-point patterns, he can lift from the surface map; precipitation areas and convection lines from the Radar Summary Chart; and cloud edges and other weather patterns of the moment from Weather Depiction Charts. From constant pressure and winds aloft charts he can note lines of zero advection of moisture or temperature, "minor" lines of convergence, the slope of frontal and pressure systems in and proximate to this area. As the forecaster selects features for the composite picture, he is establishing the initial state of the atmosphere - in a sense, the model - which will be the basis of formulating the forecast problem of the moment and going about the prognosis for a few hours. This process may be called synoptic synthesis wherein time stands still.

Prognosis by Increments

Another type of synthesis deals with time-space considerations and provides a transition from past continuity to incremental prognosis. Forecasters are familiar with the technique of showing past positions of fronts, etc., on a map. Such isochrones (lines of equal time of occurrence of an event) can be used on other pressure features such as troughs, ridges, or pressure jumps indicative of weather changes. The technique can be applied to weather events themselves which are part of a systematically moving pattern (PLATE I). Analyses of this type offer a technique for objective extrapolation into the future. Fax scheduling provides 3-hourly charts from which historical isochrones may be developed. Progs appearing on fax and the new FP3's provide guidance sources for future positions. The valid times of fax progs range upward from 12 hours, and FP3's give an interpretive word picture of various scale features. Supplying the intermediate details is the realm of the local forecaster. He should select parameters cogent to the current forecast problem, establish its continuity, and interpose future positions by one- or three-hourly increments to mesh with indications gleaned from guidance materials. This technique amounts only to formalization of mental processes that are inherent in most forecast operations now existing. It is a step toward greater objectivity and assurance of maximum utilization of guidance materials along with compatability of time and space increments of various forecasts issued. PLATE II shows 2-hourly frontal isochrones guided by continuity, local analysis, and a fax prog. The calculation of wind components normal to a front is illustrated in PLATE III.

The existing spatial distribution of weather reporting stations leaves much to be desired for tracking the small scale phenomenon and forecasting changes in it, but time-wise there is a greater abundance of data. It is evident from the work of Fujita, Teppler, and collaborators (11) that autographic records are useful in documenting mesoscale features. The standard systems of weather reporting provide only sketchy time distribution information - i.e., past weather, pressure tendency, and pressure jump data. Each station's autographic records are available for analysis and use. For a number of years trend charts have been used at aviation forecast centers for continual monitoring of terminal forecasts. PLATE IV from Air Weather Service Manual 105-51/1 (2) is an example of this type of data presentation. Saucier demonstrates the use of meteorograms ((15) Figs. 12.02 and 12.03).

Worthy of consideration in local analysis programs are space-time (x-t) methods of data organization such as is shown on accompanying PLATE V, taken from AWSM 105/51-1. Saucier (Fig. 12.04 a) shows how isobaric analysis can be applied to horizontal-time sections. Several "x" axes may be selected ahead of time and appropriate diagrams prepared for selective use dependent upon current flow patterns or translations expected.

Compositing the Vertical Picture

Planners and users of local analysis programs should not overlook the importance of sounding data in understanding and predicting weather variations. Certainly raob analysis on energy diagrams for the local area are a minimal requirement for temperature, cloudiness, and wind forecasting. Field forecasters will be interested in WB programs to expand network sounding frequency to four-times daily, and to develop a low level, inexpensive sounding capability.

They will also want to follow closely the use of data from instrumented towers (5), (7), and (12). Vertical-time sections such as those used by Gerhardt (12) and Saucier (Figs. 12.04b and 12.06a and b) may represent an optimum technique for small scale use since analysis can be continual simply by adding and analyzing data and then making pertinent extrapolations on a transparent overlay.

Low level winds are available in plotted form each six hours on national fax and may be analyzed quickly and simply on an areal basis in a manner similar to that shown on PLATE VI reproduced here from AWSM 105-35 (3).

Objective Techniques

The physical processes involved in many small scale weather variations often are obscure, difficult to define, and very difficult to express coherently, or quantitatively. Objective forecasting techniques provide systematic ways of testing theoretical concepts for forecasting versatility and of formalizing rules of thumb and correlative principles found helpful in experience (1). Forecast schemes of this type are particularly applicable to short term forecasting, for a typical one specifies the occurrence of an event at a particular place during a short time span. Developers of objective techniques usually label them as forecast aids, inferring that they are adjuncts to other systems of analysis and prediction. This is particularly true when only two or three parameters are used. When additional predictors are added to the scheme to make its application more independent, complexity in development and use increases.

There are numerous examples in the literature of objective aids for forecasting fog and stratus. A complete digest of temperature forecasting is presented in WB Forecasting Guide No. 4 (8). An idea for forecasting strong winds for boating is shown on PLATE VII based on an objective technique (21).

Various precipitation forecasting schemes have been developed utilizing different approaches. For inspiring examples one can review Brier's classic for the TVA Basin (4); Schmidt's for Washington, D. C. (16); and more recently the method explained by Rothenberg (14) in Technical Memorandum No. 11. This latter study (or rather guide for local studies) has been extensively used for successful testing of vorticity advection techniques at numerous locations in the Northern States, but no known work along this line has been done in the Southern Region.

How About More Data?

When one studies the small space-time weather regime, a logical concern develops over the adequacy and availability of data. The perfect solution to detailed forecasting must await better understanding of atmospheric processes and data networks commensurate with the outgrowing models.

In all likelihood, the existing aviation network density will need to be increased by several orders of magnitude and re-cycling rates stepped up considerably above hourly.

Studies of dense meso-net data are under way - both from the standpoint of understanding small scale processes and of forecasting them. Questions of economic feasibility will always arise concerning establishing and operating denser data networks. On the other hand, it is unlikely that field stations now are using existing data sources at a level that approaches the maximum. This is the first order of business.

Are hourly reports (both body and remarks) being used to the maximum in local analysis programs? Are supplementary sources being used - SAWRS, Oil Rig, etc? Are we squeezing the most use from expensive and highly versatile radar programs? Have we actually tried tying all existing bits of information into an isochrone approach to short period forecasting? Have we experimented with "unorthodox" types of analyses of existing data pointed toward greater discreteness? Have we exhaustively searched the literature for clues to the short term forecast problem? When such questions can be answered affirmatively, thoughts can turn to the potential of expanded data coverage.

The prospects for expanding data networks for small scale analysis is not as bleak as costs, station routine, complacency, and apathy might at first indicate. Weather effects touch most people in a meaningful way, and many are willing to cooperate by furnishing data. Weather Bureau employees and FAA people with whom we have close working relationships normally have residences scattered about the metropolitan areas, and these are logical possibilities for the nucleus of a local net. In general, WB service offices enjoy excellent work relations also with user groups in connection with storm warning and other programs. City police, fire, and water departments in outlying areas, state highway and public safety sub-offices, CD people, turnpike tenders, utilities dispatchers, commercial radio and TV stations - all these, and others, are potential data sources. Within many of these groups radio and phone nets are developing, and Federal phone facilities are becoming more versatile. Arrangements are feasible to collect reports promptly and economically.

Whither Now?

An attempt has been made to help bring into perspective some of the historical and current factors bearing upon emphasis at field stations on short term forecasting. References thought to be generally available at field stations related to the short period forecast problem have been collected. From these an approach to local analysis programs has been outlined. It is a broad-brush treatment with no specific recommendations for particular types of stations. Standardization of techniques among stations is desirable and will be feasible after a suitable period of development, testing, and pooling of experience.

In the initial phase of developing station procedures to improve short term forecasting, each field office must take on the atmosphere of a workshop of experimentation and testing. Each shop has a unique environment of weather regimes to forecast, programs to serve, staff patterns to utilize, and data sources to consider. Each also has its own sparks of talent, ambition, and leadership to kindle. Progress in short period forecasting will come only through logical and systematic application of meteorology at the hub of the problem - at the local service office.

Jeter Pruett
Scientific Services Division
Fort Worth Regional Headquarters

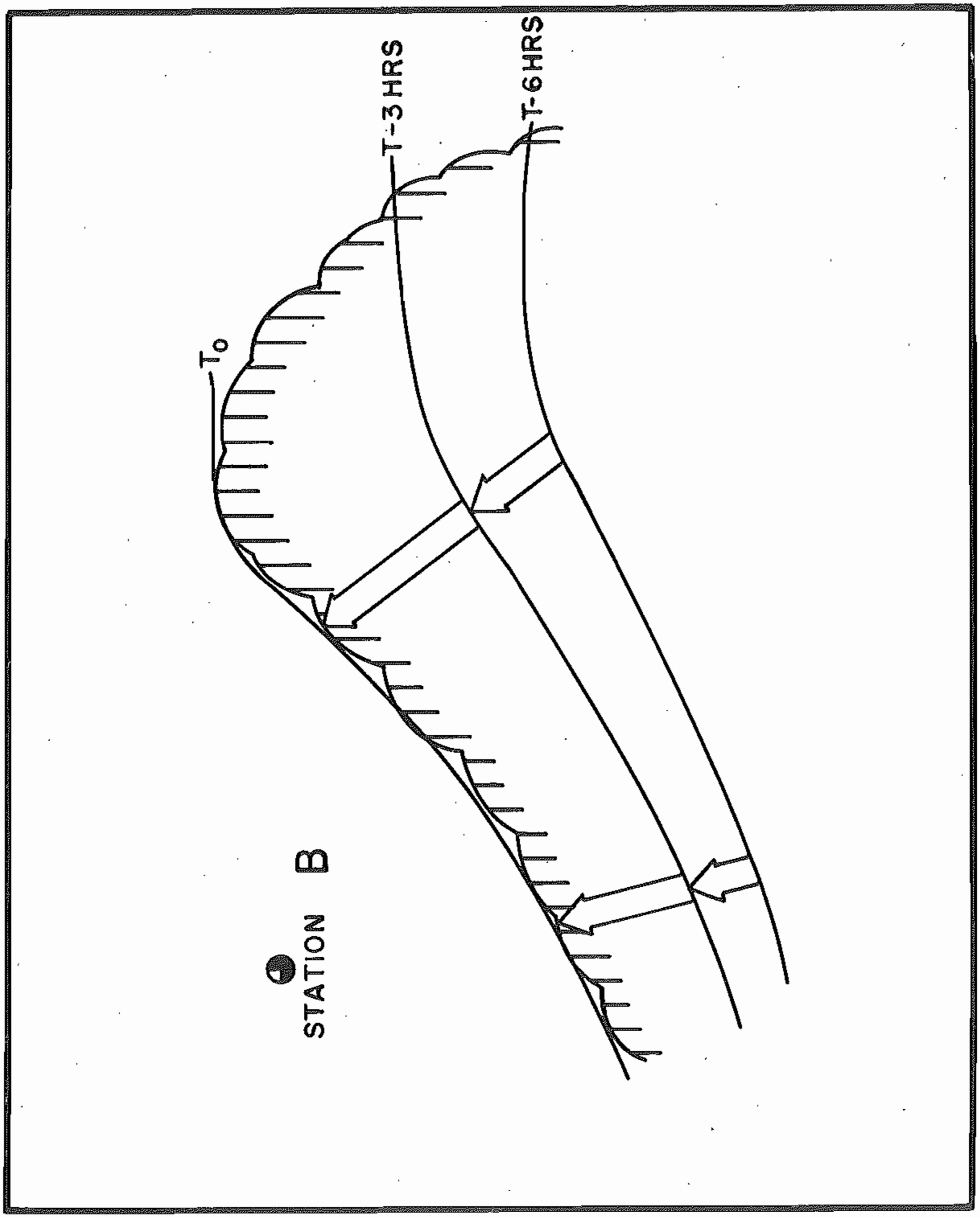


Figure 12. A Schematic Diagram of the Isochrone of the Current Position (T_0) of the Leading Edge of the Area of Ceilings Below 1500 Feet (shown in Figure 11a) with Its Two Past Positions (T-3 hours and T-6 hours).

PLATE I

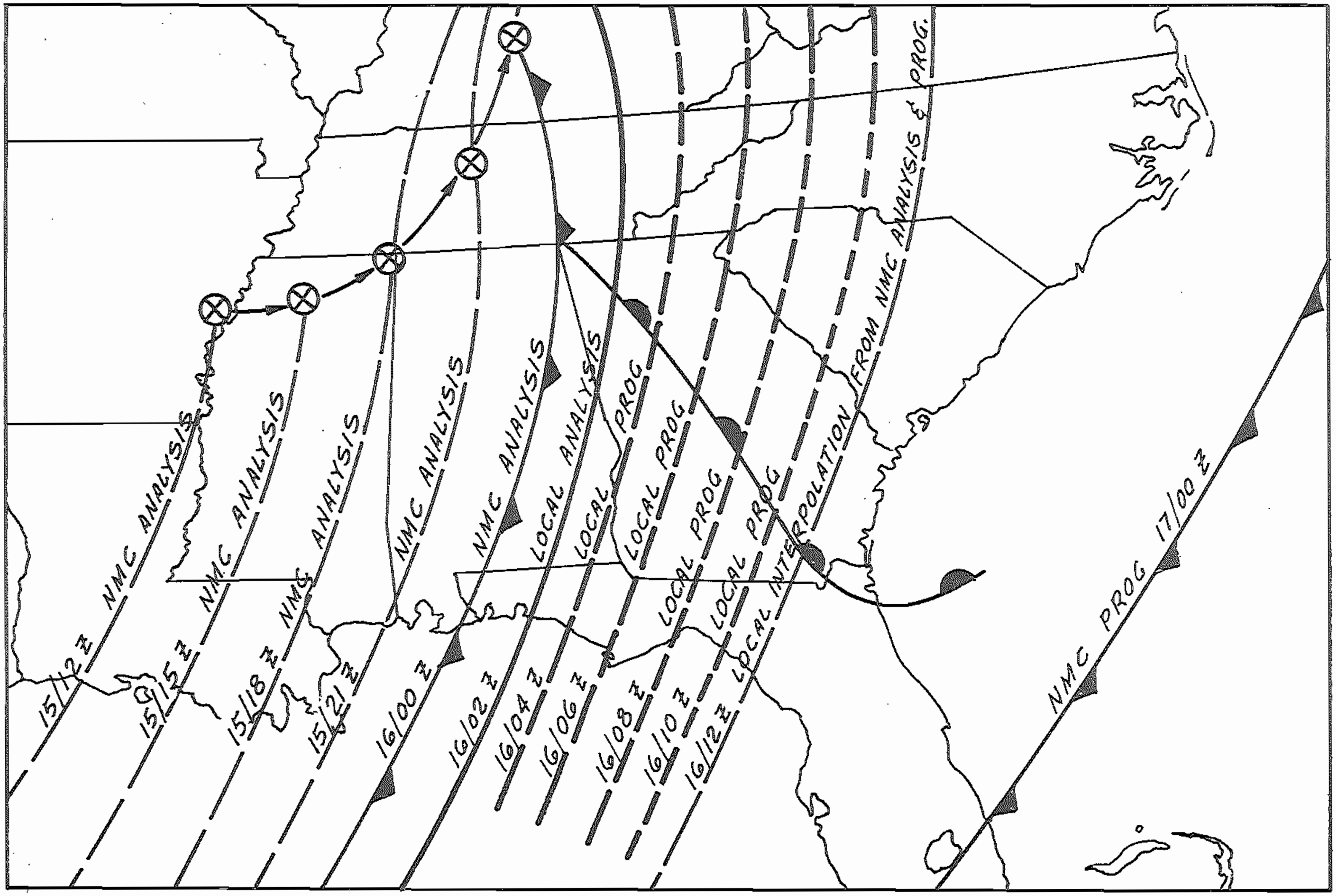
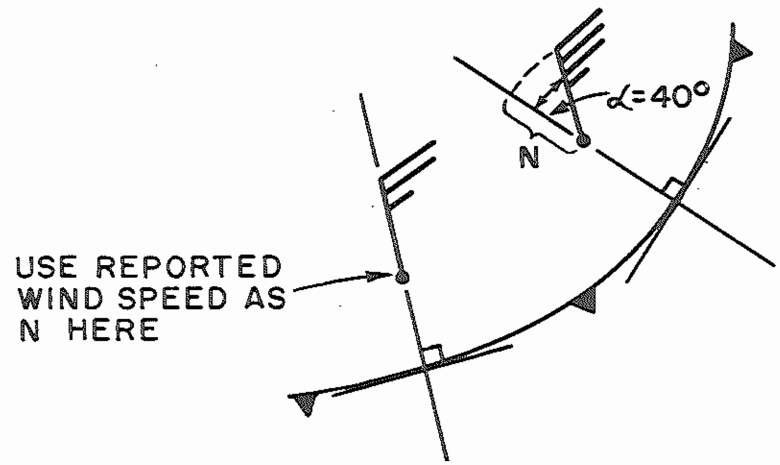


PLATE II.

Prognostic Frontal Isochrones Based on NMC Continuity, Local Analysis for 02 Z, and a 24-hour Prognostic Chart.



N = WIND COMPONENT NORMAL TO THE FRONT

α = ANGLE BETWEEN TOTAL WIND VECTOR AND COMPONENT N

$$\frac{N}{35\text{kts}} = \text{COSINE } \alpha$$

$$N = 35 \text{ COS } 40^\circ$$

$$N = 35 \times 3/4$$

$$N = 27\text{kts}$$

Figure 16. An Illustration of a Method for Calculating the Wind Component Normal to a Front by Trigonometry. In this case, an average normal component of about 25 knots is acting on the front.

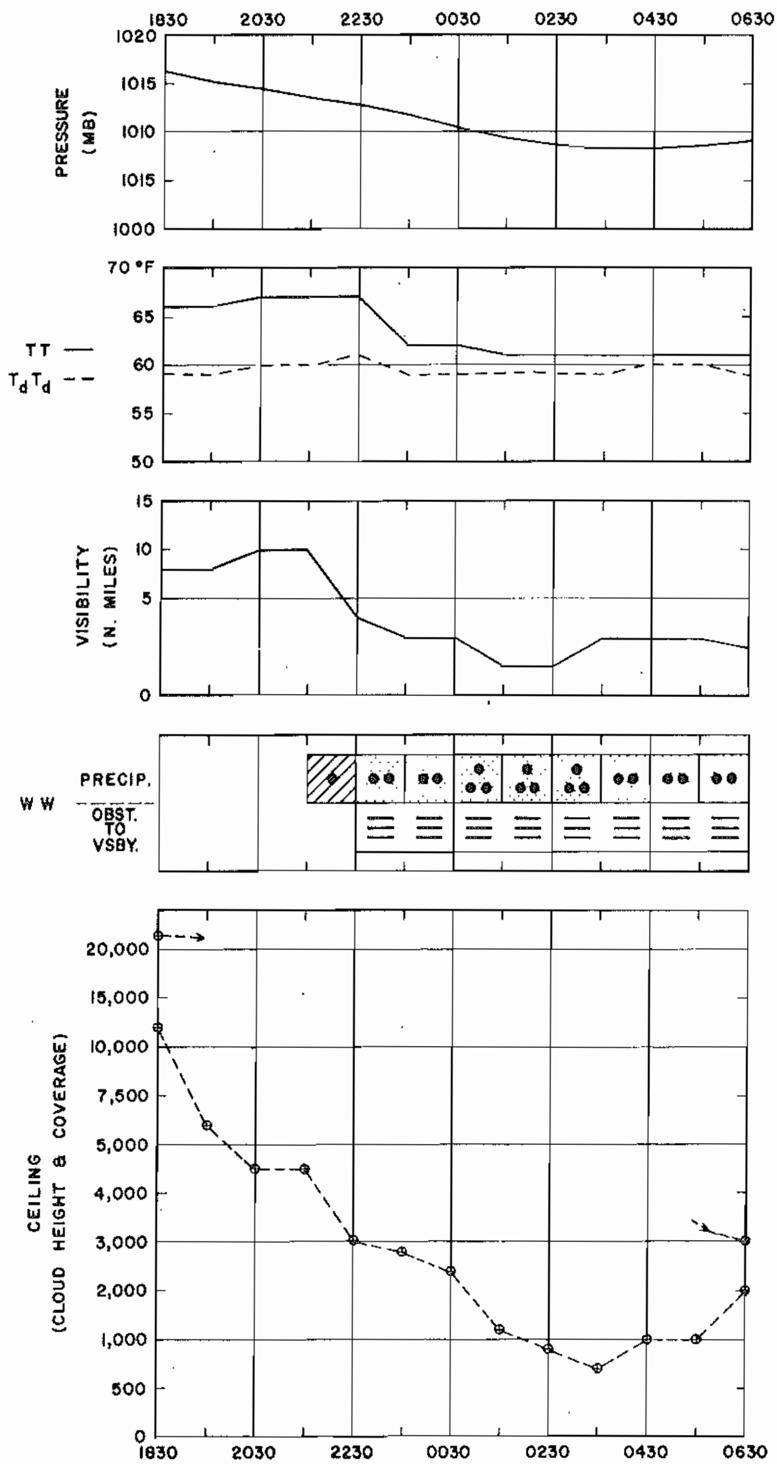


Figure 1 Trend Chart

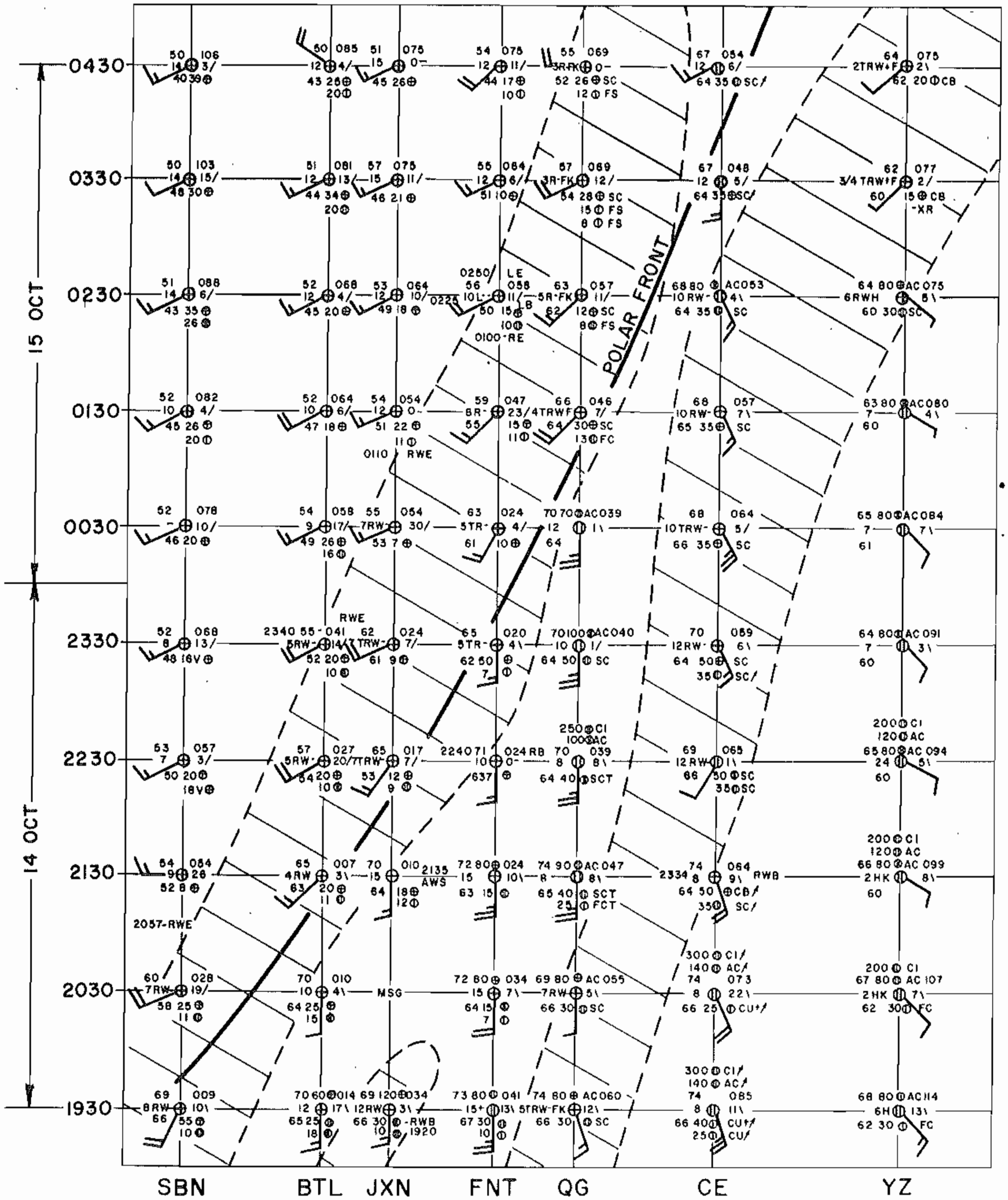


Figure 2 An Example of an x-t Diagram, 1930Z, 14 October – 0430Z, 15 October 1954. The positions of the front relative to the stations are indicated by the heavy continuous line. Showery areas are enclosed by broken lines and hatched.

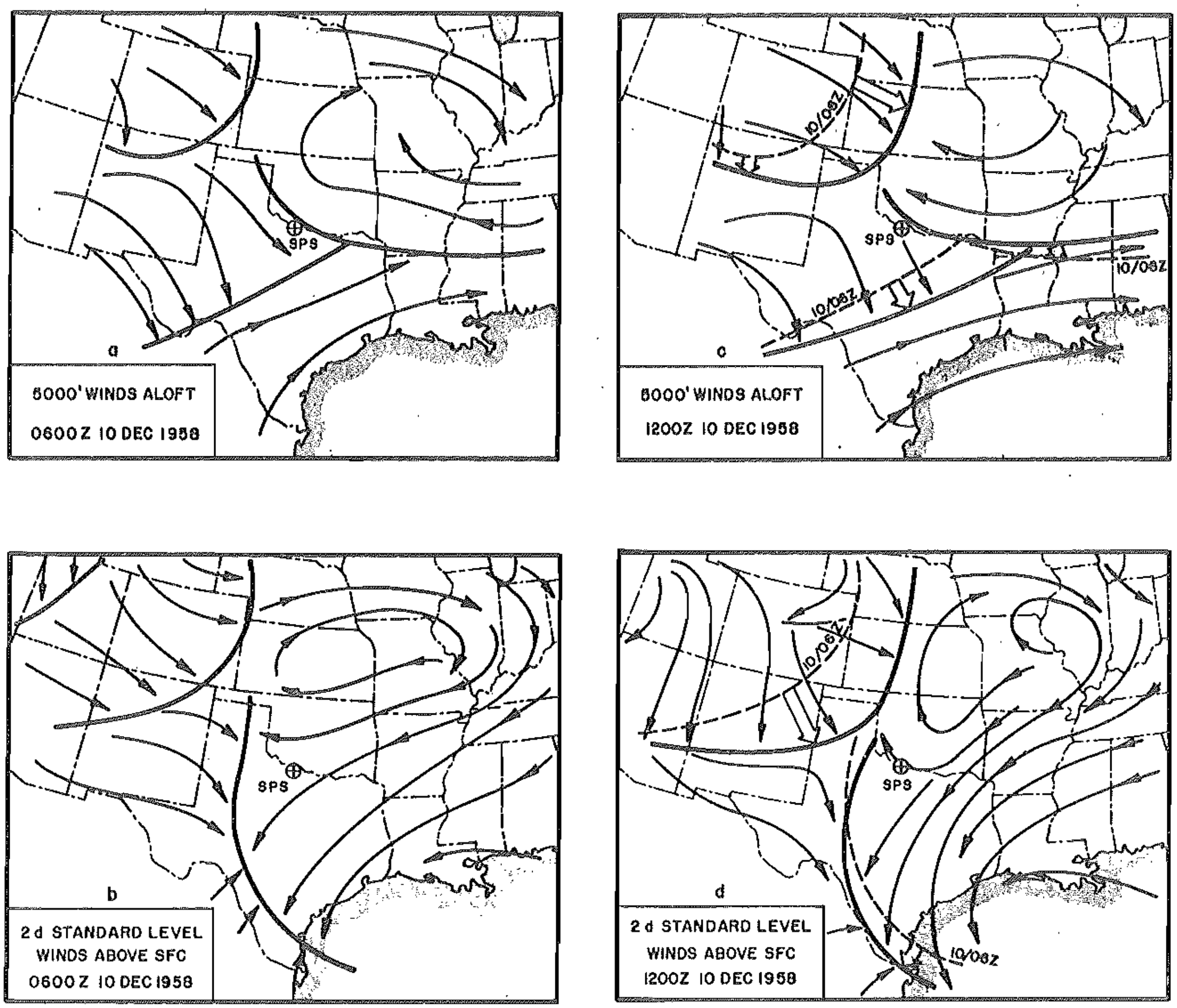


Figure 27a, b, c, d. Streamline and Trough Analysis of Two Low-Level Winds-Aloft Charts for 0600Z (Figures 27a and 27b) and 1200Z (Figures 27c and 27d), 10 December 1958. The 0600Z positions of troughs are indicated as dashed lines on the 1200Z analyses. The block arrows show the direction of the resulting 6-hour movements.

PLATE VI

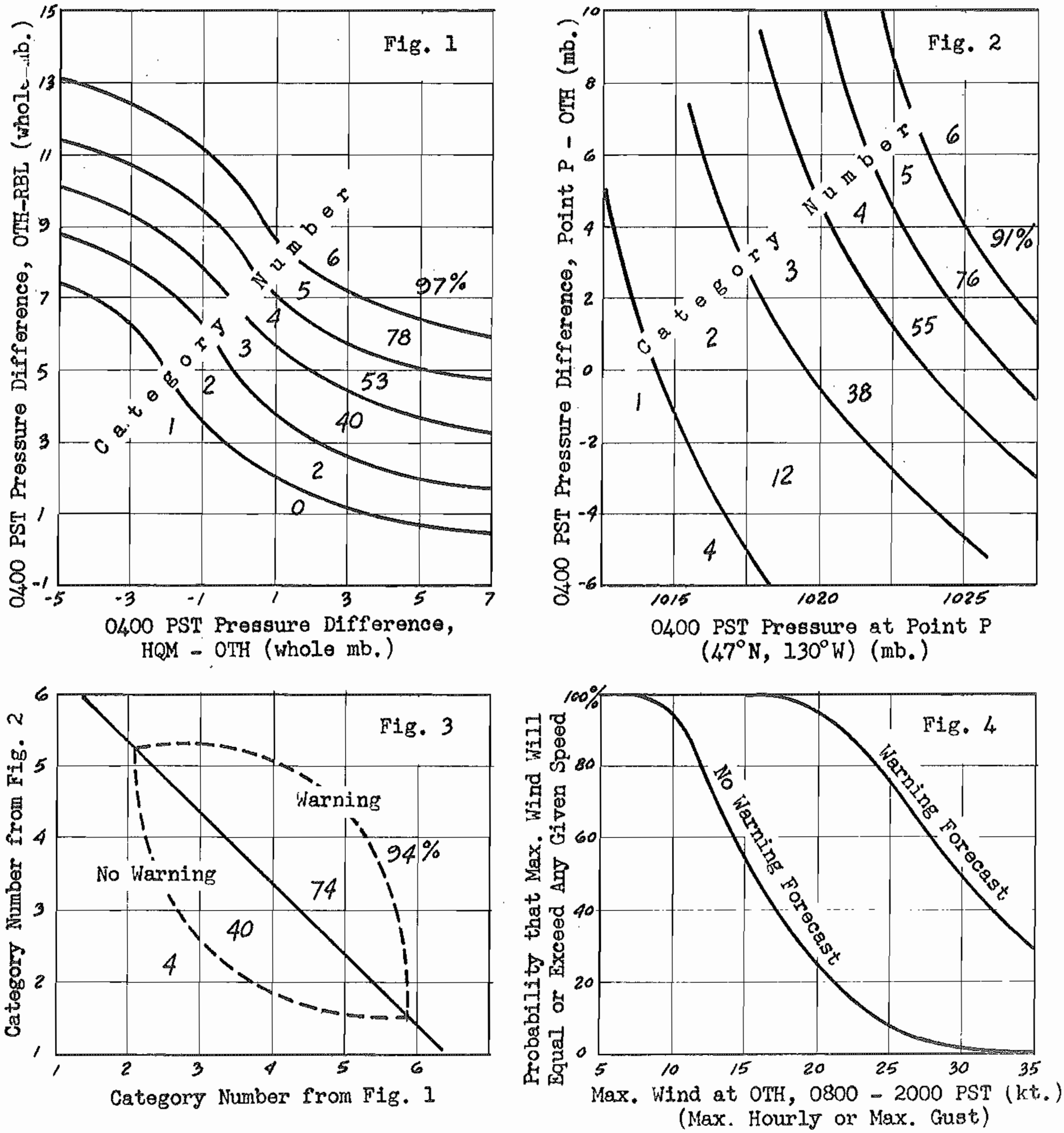


PLATE VII.

Aid developed by Wakefield and Dickey (20) for preparing daytime (08-22 PST) wind warnings (>22 kts.) at North Bend, Oregon (ORH) from 04 PST pressure observations at ORH, Red Bluff, Calif. (RBL), Hoquiam, Wash. (HQM), and Point P (47°N, 120°W). Warning cases are separated from no warning cases by the solid sloping line in Fig. 3. Note the high confidence above or below the dashed lines in Fig. 3. Given a warning or no warning determination, the probability of any maximum wind speed up to 35 kts. may be obtained from Fig. 4.

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